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Hwang

(54) **CATALYTIC ENGINE**

(75) Inventor: **Herng-Shinn Hwang**, Livingston, NJ (US)

Correspondence Address:
Herng-Shinn Hwang
62 Shrewsbury Drive
Livingston, NJ 07039 (US)

(73) Assignee: **Herng Shinn Hwang**, Livingston, NJ (US)

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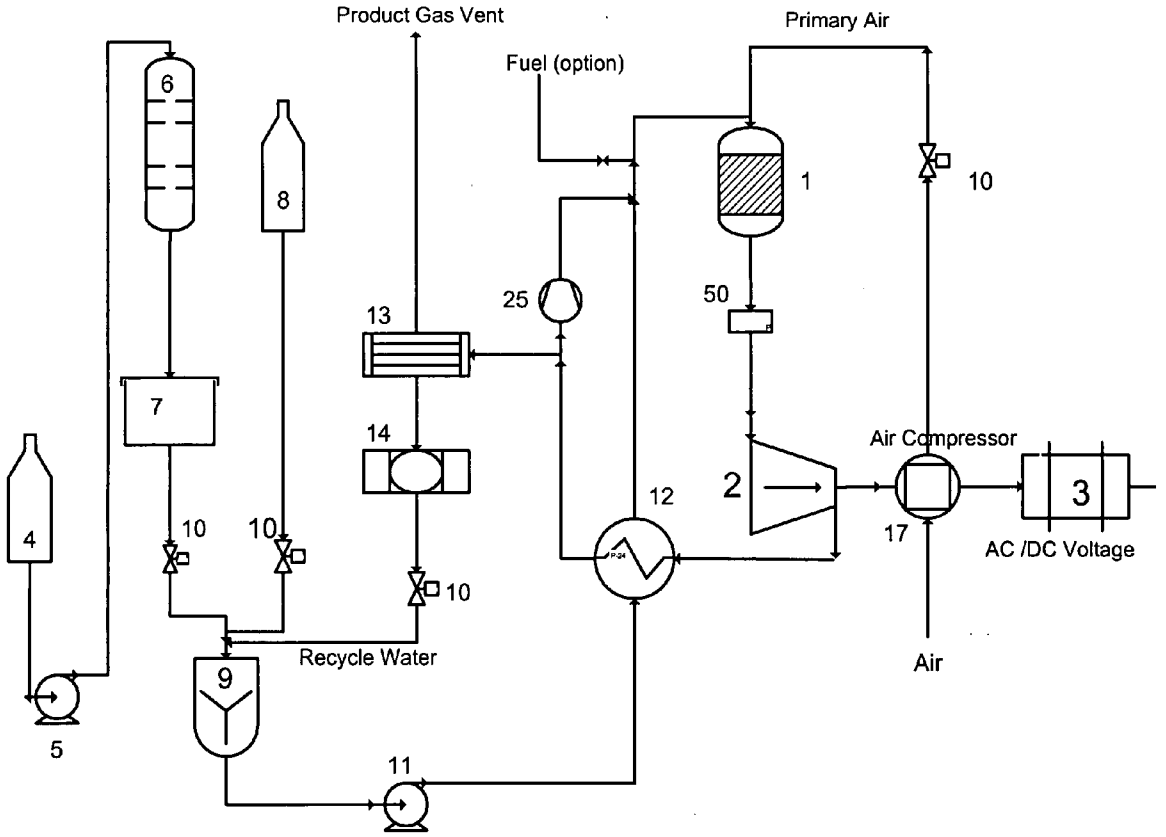
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(57) **ABSTRACT**

A catalytic engine comprises a catalytic reformer and a turbine, and it employs the process steps of introducing a reactant mixture of fuel, air, water and recycled exhaust gas into a reaction zone, reacting said fuel mixture over oxidation catalysts in the reaction zone by adjusting the CO_2/C, H_2O/C, O_2/C ratios and the % fuel of the reactant mixture to maintain the reactor at a temperature between 150-1100° C. and a pressure between 1 to 100 atmosphere, and feeding said refromate stream from said reaction zone to drive a downstream turbine, a turbocharger or any kind of gas turbine. This catalytic engine can be connected to an electrical generator to become a stationary or mobile power station, which can be used in transportation, industrial, utility and household applications.



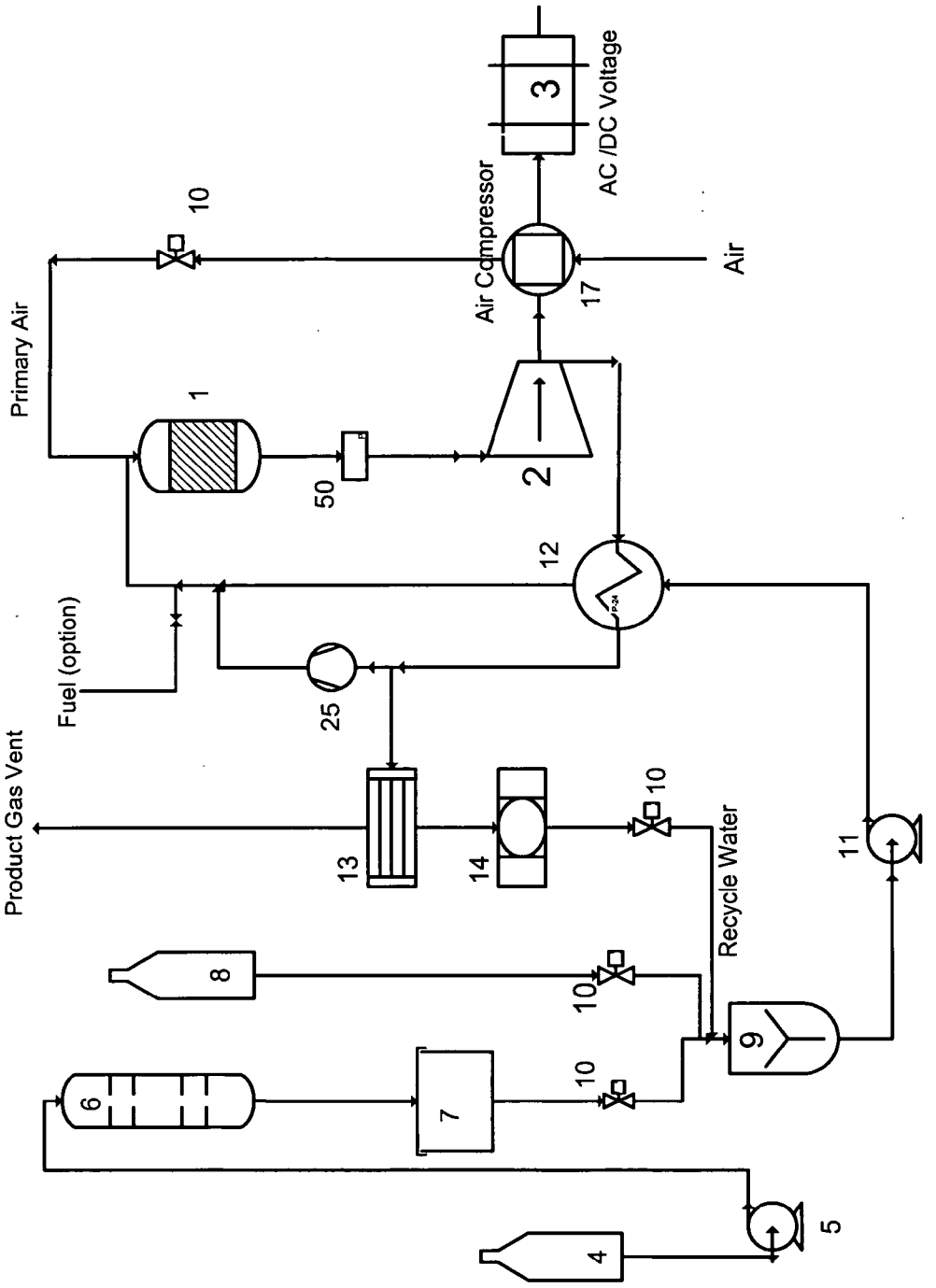

AC /DC Voltage
3
Air Compressor
17
Air
10
Primary Air
1
50
2
12
Fuel (option)
25
Product Gas Vent
13
14
10
Recycle Water
11
8
10
9
10
6
7
5
4

Fig. 1

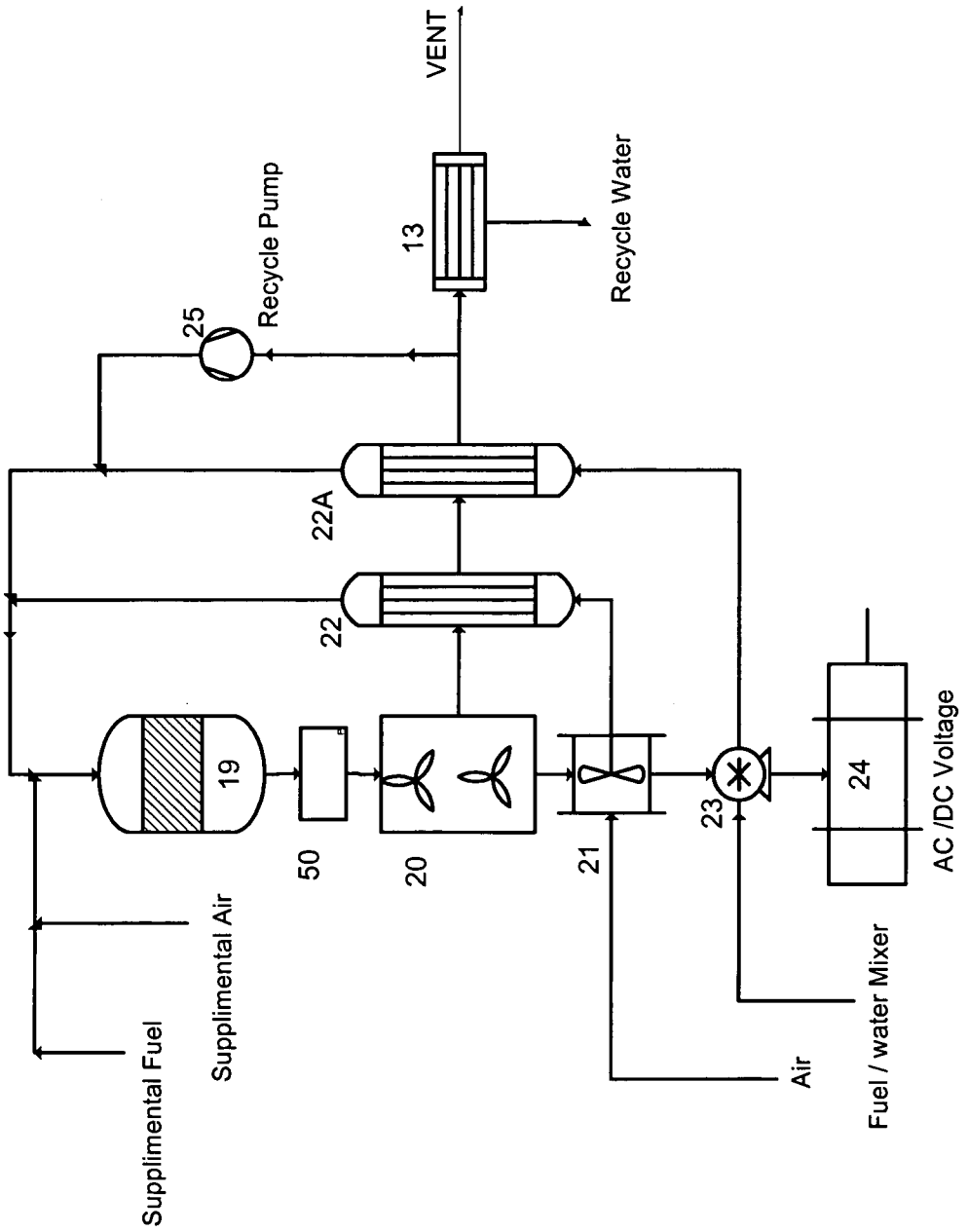

VENT
Recycle Water
13
Recycle Pump
25
22A
22
19
50
20
21
23
24
AC /DC Voltage
Supplimental Fuel
Supplimental Air
Air
Fuel / water Mixer

Fig. 2

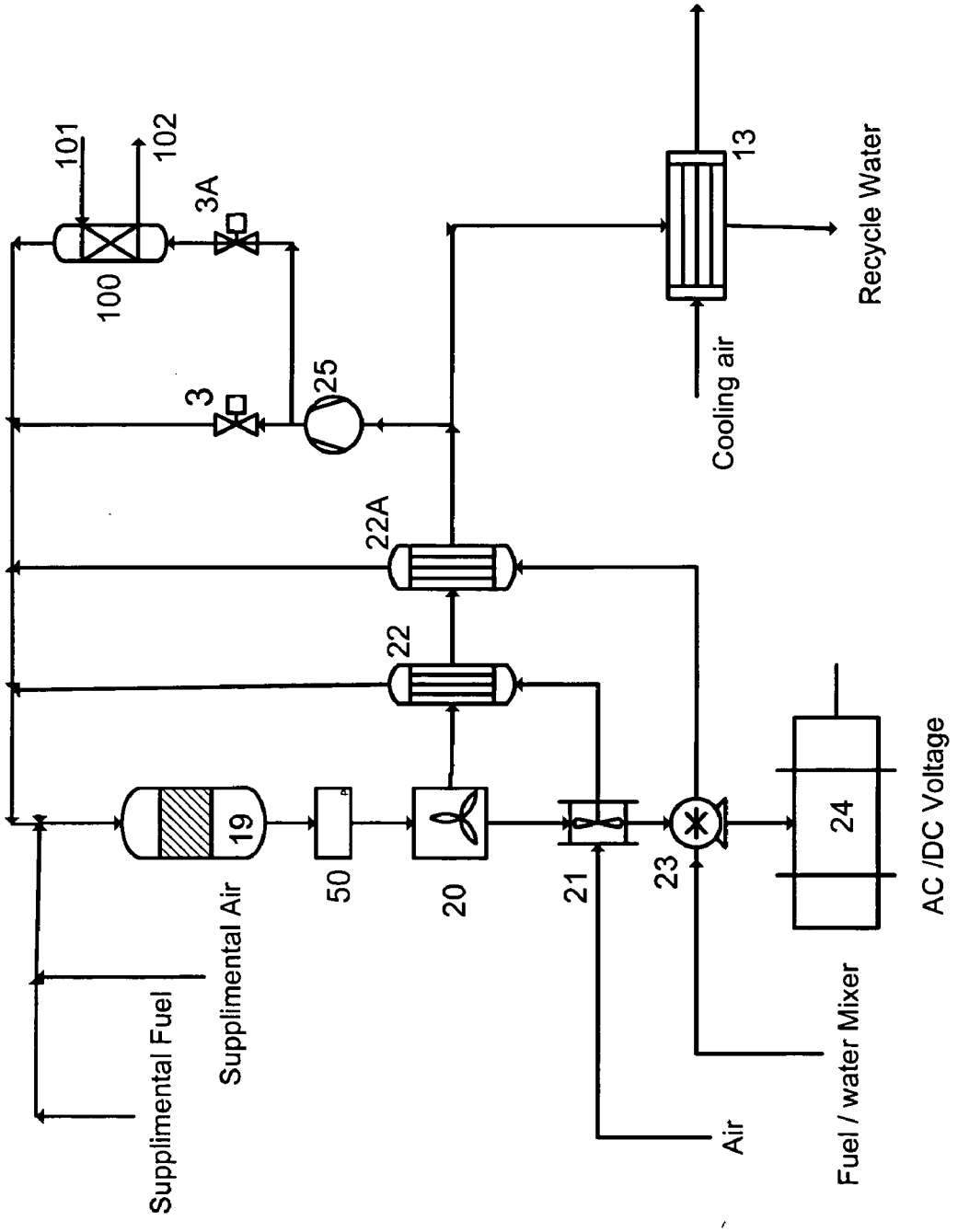

101
102
3A
100
3
25
13
Recycle Water
Cooling air
22A
22
19
50
20
21
23
24
AC /DC Voltage
Supplimental Fuel
Supplimental Air
Air
Fuel / water Mixer

Fig. 3

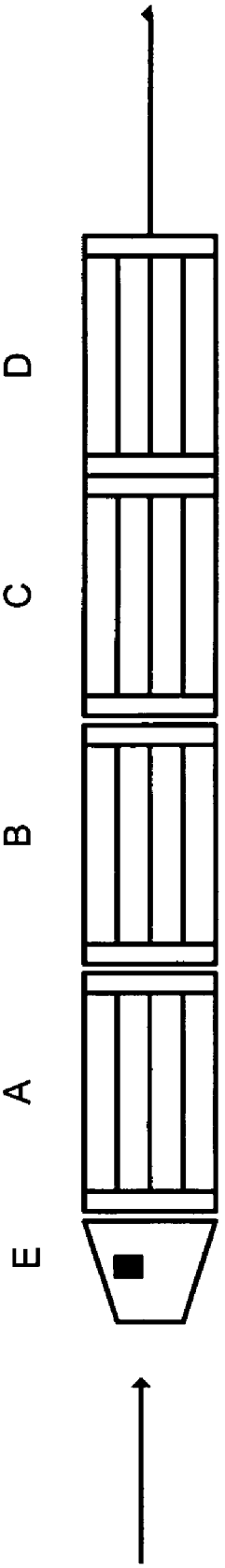


Fig. 4

CATALYTIC ENGINE

CROSS REFERENCE INFORMATION

[0001] This application claims benefit to and priority of U.S. Provisional Application No. 60/933,543 filed on Jun. 6, 2007, herein incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention describes a new low cost catalytic engine, which consists of a catalytic reformer and a turbine. This catalytic engine can be used to drive devices or equipments used for utility and transportation applications, and it can also be connected to an electric generator to become a stationary or a mobile power station.

BACKGROUND OF THE INVENTION

Conventional Power Plant Boilers

[0003] Industrial power plants for generating large scale electrical power typically burn fossil fuels and/or biomass to generate large amount of heat, which is used to produce high pressure steam in a boiler. The steam is then fed into a steam turbine to generate electricity.

[0004] Such conventional means suffer from a number of drawbacks. For example, these processes consume an enormous amount of fossil fuel, generate an excessive amount of undesirable waste heats as well as greenhouse gases and produce pollutants such as carbon dioxide, nitrogen oxides, sulfur oxides etc. Furthermore, thermal inefficiency arises when the combustion heat is transferred from the shell side to the tube side of a boiler in order to heat and produce steam for the turbine.

[0005] With worldwide fossil fuel resources slowly becoming strained and the harmful effects of excess greenhouse gases and other pollutants becoming better understood, more efficient, low cost, reliable, portable and cleaner technologies for producing electricity are needed.

Internal Combustion Engines and Gas Turbines:

[0006] In the 20th century, various type of internal combustion (IC) engines and gas turbines has successfully been developed and been widely used over the years in the stationary power generation, transportation and utility applications. For example, the 2-stroke and 4-stroke engines are used for motorcycle, chainsaw, lawn mower, weed eater, automobile, small power generator etc, the diesel engines are used for truck, bus, stationary power generator etc, and the gas turbines are used for airplanes, power generators etc. Currently, most of the IC engines and gas turbines utilize homogeneous flame combustion of various hydrocarbons (HC) to generate power, and it is known that the timing of ignition, the composition of the fuel/air mixture, the vaporization of the fuels, and the temperature and pressure at the ignition point are very important for a complete combustion. However, despite all the necessary controls and the technology advances over the years, any internal combustion engine or gas turbine will still emit pollutants such as unburned hydrocarbons, CO, NO_x, diesel particulates etc.

[0007] To reduce the HC, CO, NO_x and diesel particulate pollutants from the internal combustion engine's exhaust, catalytic converters and/or diesel particulate traps containing supported Pt group metal catalyst have successfully been used commercially for several decades. However, for this pollution removing technology, it is necessary to use an on-board computer as well as various electronic/mechanical devices to reduce the pollutants by controlling precisely the ignition timing, and the air/fuel ratio of the combustion gas. Also, these devices are required to improve the efficiency of the catalytic converters or traps, which are installed in the engine's exhaust pipe lines.

[0008] Various other types of IC engines have also been developed successfully in recent years, and these engines can use different fuels such as hydrogen, natural gas, liquefied propane gas, gasoline/ethanol mixture (flex fuel), diesel/biodiesel mixture etc. Catalytic Combustion Technology:

[0009] Since 1970's, extensive research and development on catalytic combustion technologies have been studied over the years. As demonstrated in U.S. Pat. No. 3,975,900, U.S. Pat. No. 5,235,804, U.S. Pat. No. 5,326,253 and U.S. Pat. No. 6,358,040, herein incorporated by references, the catalytic combustion of HC over the supported Pd and other catalysts using various type of reactor designs can reduce the reaction's peak temperature and, thus, can reduce the formation of NO_x, while achieving low CO and HC emissions. However, the reaction peak temperatures are frequently found to be exceeding the upper limits of the catalyst, and they would shorten the catalyst life and cause failures during the applications.

[0010] In U.S. Pat. No. 6,960,840 to Willis et al, herein incorporated by reference, two catalytic reactors are used with a gas turbine generator to achieve better exhaust emission. Air and natural gas are first compressed and heat exchanged and a primary catalytic reactor is used to raise the turbine's inlet temperature. After the turbine, a second low-pressure catalytic reactor is used to combust the remaining fuels and to recover the heat.

[0011] When water, CO_2 or the recycled exhaust gas (contains steam and CO_2) are not part of the feed mixture as shown by various catalytic combustion technologies, the produced reaction heats are not absorbed by these steam and CO_2, which are high heat capacity compounds. Therefore, a sudden momentary increase in O_2/C ratio of the feed mixture can cause the run away oxidation reactions over the Pt group metal and/or commercial oxidation catalysts, and produce within a few milliseconds excess reaction heats. These heats can permanently deactivate or even melt and destroy the catalysts, and thus reduce the reactor's reliability and its useful life.

Fuel Cells Cars and Buses:

[0012] Fuel cells offer much promise and potential as a more efficient and cleaner process for generating electricity. Therefore, fuel cells can potentially be used to replace the internal combustion engines for the stationary power generation, utility and the transportation applications.

[0013] A number of different fuel cells are known in the art, including but not limited to Solid Oxide Fuel Cell (SOFC), Proton Exchange Membrane Fuel Cell (PEMFC), Phosphoric Acid Fuel Cell (PAFC), Alkaline Fuel Cell (AFC), Molten Carbon Fuel Cell (MCFC), Direct Methanol Fuel Cell etc. Since PEMFC and SOFC can provide higher power density, they are considered to be the leading fuel cell technologies for automobile and bus.

[0014] In its simplest form, fuel cells produce electricity through reactions between fuel and an oxidant brought into contact with two catalytic electrodes and an electrolyte. For example, hydrogen fuel and oxygen are reacted over electrodes to produce water (steam) and electricity by an electro-

chemical process. Other byproducts such as carbon dioxide may be present as well. The result is a far more thermally efficient and cleaner process for generating electricity.

[0015] However, despite the technology improvements in recent years, every fuel cell technology has limited short operating life, difficult for mass production, and still very expensive and unreliable. Therefore, the commercialization of hydrogen fuel cells for large scale applications is still under development and is expected to remain so in the near future. For example, PEMFC requires a constant and continuous supply of hydrogen to generate electricity and thus, a reliable source of hydrogen becomes a limitation in this process. Furthermore, fuel cell catalysts are sensitive to some residual hydrocarbons and/or impurities such as sulfur, calcium, magnesium etc. and thus, the hydrogen fuel also needs to be purified, a yet further limitation of this process. Another required improvement in fuel cell technology is the seamless integration of the fuel reformer and the fuel cell stack for long hour continuous and reliable operation. A sudden increase/decrease in power requirement can cause flow disturbance to the reformer and thus create unstable operation in the fuel cell stacks.

Fuel Pretreater, Vaporizer and Delivery System:

[0016] In U.S. Pat. No. 6,415,755 to Lathi and Johnson, herein incorporated by reference, a plate or a tube fuel processor is used to vaporize the fuel with the hot exhaust gas before injecting the fuel into a combustion source. In U.S. Pat. No. 5,794,601 to Pantone, herein incorporated by reference, a fuel pretreating apparatus and the method for pretreating an alternate fuel for internal combustion engines, furnaces, boilers and turbines are described. In this patent, an engine's by-pass exhaust stream is used to vaporize fuel in a volatilization chamber and also to carry this HC fuel through a heated reactor prior to its being introduced into the fuel burning equipment, such as an IC engine. The reactor is preferably interposed in the exhaust conduit and is formed by a reactor tube having a reactor rod mounted coaxially therein in spaced relationship. The exhaust stream passing through the exhaust conduit provides the thermal energy to the reactor to pretreat the vaporized fuel stream. This fuel processor for pretreating the fuels was later explained by the inventor as a self-inducing plasma generator. In this patent, the Pt group metal and/or commercial oxidation catalysts and the catalytic processes were not used to carry out the oxidation reactions of the fuels with the recycled exhaust gas, and it did not describe the requirement and necessity of controlling the O_2/C, H_2O/C and CO_2/C ratios of the fuel mixture.

Integrated Catalytic and Turbine System and Process for the Generation of Electricity:

[0017] A co-pending application U.S. Ser. No. 11/711988 was filed on Feb. 28, 2007. According to this invention, a single integrated catalytic and turbine generator or a system combining in series several single integrated catalytic and turbine generators can be used to generate electricity. For example, a fuel mixture comprising the HC (or bio-fuel), steam and an oxygen containing gas are introduced into the reformer and are reacted over a Pt group metal catalyst in a reaction zone to produce a high pressure reformate containing steam, H_2, CO, CO_2, N_2, O_2 and unconverted HC. This high-pressure reformate stream can be used to drive a turbine and a generator to produce electricity. However, to improve the durability of the catalyst life, the H_2O/C and O_2/C ratios of the feed stream must be controlled individually and/or simultaneously so that the temperature in the reactor zone can continuously be kept between 150 and 1200° C., preferably between 150 and 1100° C.

[0018] From thermodynamic equilibrium calculations as demonstrated in this co-pending patent application, the addition of water (the term "water" encompass "steam") into the air and fuel feed mixture can reduce the adiabatic temperature, and the reactor can be operated without coke formation in a broader range of O_2/C and H_2O/C ratios. In addition, due to higher heat capacity, the oxidation reactions of the fuels in the presence of steam can reduce the reaction peak temperature and thus can improve the durability, life and the performance of the catalyst.

[0019] In this invention, the above integrated catalytic and turbine generator system can be simplified by operating the reformer at higher O_2/C, H_2O/C and CO_2/C ratios but with limited % fuel in the feed mixture. For example, additional CO_2, air, water and the recycled reformate (contains steam and CO_2) can be injected into the feed stream of a reactor to increase these ratios. Since both CO_2 and steam, which have higher heat capacity, can absorb more reaction heats and since the % fuel in the feed mixture is controlled below a certain level to limit the total (maximum) amount of reaction heat produced, a single reformer can be operated at a temperature below 1200° C. without producing any pollutants. It is known that, under the excess oxygen condition, only the catalytic complete combustion reactions of fuels will occur, and the catalytic partial oxidation reactions of fuels to produce H_2 and CO can be avoided. Therefore, the reformer in this invention will use complete oxidation reactions of fuels to generate heat to provide a high temperature and high pressure reformate for the turbine.

[0020] The present invention addresses the shortcomings of other integrated systems and provides an alternate low cost and reliable catalytic engine, which can be used alone or can be combined with a generator to produce electricity to be used for the applications in transportation, utility and stationary or mobile power generation.

[0021] This catalytic engine can use most of the hydrocarbons and/or renewable energy fuels in an efficient, clean and readily available manner. Furthermore, during the energy transformation processes, the atmospheric CO_2 can be recycled and be converted naturally by tree, grass and plants into various products, and these products can then be made into energy fuels. Thus, the net CO_2 produced from these fuels by this invention is counted as zero according to the Kyoto Protocol. In other words, the use of renewable bio-fuels for the catalytic engine by this invention can effectively reduce the overall greenhouse gas production.

SUMMARY OF THE INVENTION

[0022] There is a provided a catalytic engine comprising (1). The process steps of introducing a reactant mixture of limited % fuel, water, portion of the engine's (recycled) exhaust gas and supplemental amount of air in a given range of O_2/C, H_2O/C and CO_2/C ratios into a reaction zone (i.e. oxidizer), (2). Reacting said reactant mixture over Pt group metal and/or commercial oxidation catalysts in said reaction zone by complete combustion reactions at a given temperature between 150-1200° C. and a pressure between 1 to 100 atmosphere to produce rapidly (typically <300 milliseconds) and directly without using a heat exchanger a reformate

stream comprising mainly of steam, CO_2, N_2 and O_2, and (3). Feeding said high pressure reformate stream from said reaction zone to drive a downstream steam turbine, turbocharger or any type of gas turbine. This catalytic engine can be used directly to drive devices or equipments used for transportation and utility applications, or it can optionally be connected to an electric generator to produce electricity and be used as a stationary or a mobile power station.

[0023] The new and novel catalytic engine is consisting of a catalytic reformer and a turbine. The fuel mixture feeding into the reformer of this catalytic engine comprises fuel or a fuel mixture, steam, a recycled reformate stream with optionally additional controlled amount of air. The fuels mentioned here are C_1-C_{16} hydrocarbons, C_1-C_8 alcohols, vegetable oils, bio-ethanol, bio-diesel, any fuels derived from biomass or from agriculture/industrial/animal wastes etc. In other words, any fossil or bio-fuels, which can completely be oxidized with excess oxygen over the Pt group metal and/or commercial oxidation catalysts, are good candidates for this invention.

[0024] The reaction zone includes a catalyst composition comprising one or more Pt group metals and/or commercial oxidation catalysts preferably supported on various types of ceramic monolith, metallic monolith, pellet, wire mesh, screen, foam, gauge, plate etc. To improve the catalyst's durability and increase the engine's operating life, it is necessary to optimize and control individually or simultaneously the % fuel, H_2O/C, CO_2/C and O_2/C ratios in the feed mixture so that the reactor's catalyst temperature is constantly kept below 1200° C. (preferably <1100° C.). Depend on the latent heat of the fuiel used; the maximum % fuel in the feed mixture can be various. But, it must have an upper limit to avoid producing too much combustion heats, which will deactivate or even melt the catalyst. Furthermore, the H_2O/C ratio is preferably greater than 3.0, the O_2/C ratio greater than 1.0, and the CO_2/C ratio >0.05. However, the CO_2/C ratio can be 0.0 if the exhaust gas is not recycled back to the system.

[0025] Since the turbine and/or the turbo charger are driven by pressure, the gas composition in each reformate mixture is not an important factor in driving the turbine or a turbocharger. Therefore, contrary to the fuel cell applications where the O_2/C ratio must be limited within a very narrow range so that the reformer can produce CO and H_2 by the catalytic partial oxidation reactions, the operating conditions in this invention to generate high pressure reformate stream can be optimized in a much wider O_2/C range in a reaction zone. Furthermore, in order to be a pollution free catalytic engine, excess oxygen should be provided to the feed mixture so that the HC or fuels will be completely combusted over the Pt group metal and/or commercial oxidation catalyst into CO_2 and H_2O, and the final vent gas will consist mainly of steam (water), CO_2, O_2 and N_2.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. **1** is a schematic illustration of an integrated system containing a catalytic engine for generating electricity in accordance with an exemplary embodiment of the present invention.

[0027] FIG. **2** is a schematic illustration of a catalytic engine for generating electricity in accordance with an alternative exemplary embodiment of the present invention.

[0028] FIG. **3** is a schematic illustration for a process of using this catalytic engine to convert combustible gaseous and/or liquid organic wastes into electricity.

[0029] FIG. **4** is a schematic illustration of catalysts being used inside the reaction zone in accordance with the exemplary embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] A new and novel catalytic engine consisting of a catalytic reformer and a turbine is provided. It can be combined with a generator to produce electricity from hydrocarbon and/or any renewable bio-fuels. This new catalytic engine comprises introducing a fuel mixture into a reaction zone, reacting said fuel mixture over a Pt group metal and/or a commercial oxidation catalyst with recycled exhaust gas and/or additional excess amount of air to produce a high-pressure and high temperature reformate stream, feeding said reformate stream from said reaction zone to drive a turbine or a turbo charger.

Hydrocarbon Reaction Zone

[0031] In the first step of the process for the present invention, a fuel mixture is introduced into a reaction zone. The reactant mixture may comprise of fuels, steam, an oxygen containing gas and/or a recycled reformate gas containing steam and CO_2. The fuels may be any C_1-C_{16} hydrocarbons, C_1-C_8 alcohols, vegetable oils, bio-ethanol, bio-diesel, any combustible fuels derived from biomass or from agriculture/industrial/animal wastes etc. Typical useful fuels which can completely be oxidized over a Pt group metal and/or a commercial oxidation catalyst in a catalytic reactor include but are not limited to C_1-C_{16} hydrocarbons (methane, LPG, gasoline, diesel, jet fuels), natural gas, sugar, glucose, animal fats, C_1-C_8 alcohols, vegetable oils, soybean oil, corn oil, olive oil, jatropha oil, bio-ethanol, bio-diesel, biobutanol, bio-methane, bio-fuels derived from biomass or from agriculture/industrial/animal wastes, an industrial waste exhaust containing volatile organic compounds (VOC, mainly organic solvents) etc.

[0032] The oxygen containing gas may be air, oxygen or any other gaseous mixture such as recycled exhaust gas, which contains oxygen, CO_2 and steam (water).

[0033] The fuel, steam, oxygen and/or the recycled reformate may be mixed prior to feeding into the reaction zone, or may be fed separately into the reaction zone. Even if the reactants are introduced into the reaction zone separately, they become mixed in the reaction zone, and thus, this embodiment is still encompassed by the language used herein that the fuel mixture is introduced into the reaction zone.

[0034] Any conventional reactors may be used as the reaction zone. The reactor may take the form of a reformate generator or a reformer.

[0035] The reaction zone includes a catalyst composition, which can be a Pt group metal and/or commercial oxidation catalyst unsupported or supported with any known supports. If supported, the Pt group metals can be deposited on the surface of the support directly, or they can first be supported on a high surface area washcoat material, and this catalyzed washcoat can then be coated on the surface of a more thermally stable low surface area material. Examples of viable high surface area washcoat support include but are not limited to alumina, alumina-silica, alumina-silica-titania, cerium oxides, zirconium oxide, cerium-zirconium-rare earth oxide and its composite, and other oxide composite thereof. Furthermore, one or more rare earth metal oxides, alkaline oxides

and/or the oxides of lanthanum, cerium, zirconium, praseodymium, yttrium, calcium, barium, strontium, magnesium etc can be used to stabilize thermally the above washcoat materials. Examples of the low surface area supports can be any high temperature metals or ceramic materials such as mullite, cordierite, zirconia-spinel, zirconia-mullite, silicon carbide etc. These low surface area supports are substantially inert rigid materials, which are capable of maintaining their shape, surface area and a sufficient degree of mechanical strength at high temperatures. In other words, the catalyst composition including at least one Pt group metal components such as platinum, palladium, rhodium, iridium, osmium and ruthenium or mixtures thereof is preferably supported on a high surface area washcoat, and this catalyzed washcoat is then supported on various types and shapes of ceramic monolith, metallic monolith, pellet, bead, gauze, wire mesh, screen, foam, plate etc. Furthermore, other metals may also be present in the washcoat, including the base metals of Group VII and metals of Groups VB, VIB and VIB of the Periodic Table of Elements (e.g., chromium, copper, vanadium, cobalt, nickel, iron, etc). Though the applications and the operation conditions are different, typical standard preparation and composition of the supported ceramic or metallic Pt group metal catalysts, which are originally designed for fuel cell reformers as described in U.S. Pat. No. 4,522,894, U.S. Pat. No. 6,436,363 and U.S. Pat. No. 6,977,067, can be used to oxidize all fuels and can successfully be used for this invention.

[0036] The catalyst composition in the reaction zone serves to facilitate or promote combustion reactions among the fuel, steam and oxygen. Because the catalysts are prone to deactivation and breakdown at high temperatures (e.g., exceeding 1200° C.), it is preferred that the reaction zone be kept at temperatures between 150-1200° C., preferably between 150-1100° C. To initiate the reactions, the fuel mixture and the reaction zone may be preheated using any known conventional means to a temperature between 150-600° C. Or an electric hot wire, glow plug, spark plug or electric monolithic catalyst can also be used to preheat the fuel mixture instead. Once the hot exhaust gas is available and the fuel mixture contains at least one low temperature light-off chemical compound or a starter fluid, the oxidation reactions can be started by the hot recycled exhaust gas at a temperature <250° C.

[0037] In the present invention, the fuel mixture is reacted over catalyst with excess oxygen to form a high temperature and high-pressure reformate stream comprising steam (preferably >20%), CO_2, N_2, and unconverted O_2. To produce high temperature and high-pressure reformate stream, several key ratios (factors) must be monitored in the fuel feed mixture: a) H_2O to C ratio, b) O_2 to C ratio and c), CO_2/C ratio and (d) % fuel. More specifically, it is preferred that the H_2O to C ratio is greater than 3.0, the O_2 to C ratio is over 1.0 and CO_2/C ratio is over 0.05. Furthermore, depend on the latent heat of the fuel used; the maximum % fuel in the feed mixture can be various. But, it must have an upper limit to avoid producing too much combustion heats, which will deactivate or even melt the catalyst. Since the latent heats of all useful fuels vary in a wide range and the oxidation reactions over Pt group metal and/or commercial oxidation catalysts of every fuel mentioned in this invention are very fast, these ratios should be controlled individually and/or simultaneously depending on the specific fuel mixture composition to keep the reactions above a minimum operating temperature, and also to limit the reformer's maximum operating temperature below 1200° C. (preferably below 1100° C.). The adjustments of these ratios to control the reaction zone temperature can be within and/or outside the operating ranges mentioned previously and are within the skills of one skilled in the art.

[0038] For example, when methane is used as the hydrocarbon fuel, the following reactions are known to occur:

[0039] Catalytic Combustion: $CH_4+2\ O_2 \rightarrow CO_2+2\ H_2O$

[0040] Catalytic Partial Oxidation Reaction: $CH_4+\frac{1}{2}\ O_2=CO+2\ H_2$

[0041] Steam Reforming Reaction: $CH_4+H_2O=CO+3\ H_2$

[0042] Water Gas Shift Reaction: $CO+H_2O \rightarrow CO_2+H_2$

[0043] On the other hand, when ethanol is the fuel, the following reactions occur:

[0044] Complete Combustion: $C_2H_5OH+3\ O_2 \rightarrow 2\ CO_2+3\ H_2O$

[0045] Catalytic Partial Oxidation: $C_2H_5OH+\frac{1}{2}\ O_2 \rightarrow 2\ CO+3\ H_2$

[0046] Thus, different fuels result in different amounts of CO_2 and water (e.g. steam).

[0047] Since only one reformer is used, excess oxygen must be used to assure complete combustion reactions of fuels over the catalyst. Otherwise, the catalytic partial oxidation reactions will occur in the reformer, and they will produce the intermediate product such as CO, H_2 and unconverted HC. In this case, some energy is wasted and pollutants are produced.

[0048] One skilled in the art would thus appreciate that the % fuel, CO_2/C, O_2/C and H_2O/C ratios should be adjusted for optimal operating conditions in the reaction zone (i.e. 150 - 1200° C.) due to the difference in oxidation reaction heats and product quantity.

The Generation of Electricity

[0049] Once the fuel mixture is reacted to produce a reformate stream comprising mainly steam, CO_2, N_2, and O_2, the high temperature and high pressure stream can be used to drive a turbine or a turbo charger, and the turbine or turbo charger is thus said to be in communication with the reaction zone. Therefore, the reformer and the turbine and/or turbocharger are considered as parts of a catalytic engine.

[0050] If this catalytic engine is connected to an electric generator, it can generate electricity as a stand-alone stationary or mobile power station.

Gas and Liquid Waste Treatment:

[0051] If this catalytic engine is connected to an adsorption or an absorption tower, the combustible gaseous or liquid wastes can be concentrated inside the tower by the adsorption or absorption processes. Typical adsorbent/absorbent such as high surface area activated carbon, aluminum oxide, silica oxide, zeolite etc can be used as a concentrator in the tower either in a fixed or a fluidized bed design. After reaching the saturation capacity, the concentrated wastes can be purged out from the tower by the recycled hot exhaust gas, and be injected with additional controlled amount of air, water and fuels into the reformer. Again, by controlling the % fuel, H_2O/C, O_2/C and CO_2/C ratios and the reactor temperature, the combustible wastes can be converted completely by the oxidation reactions over the Pt group metal and/or commer-

cial oxidation catalysts into CO_2 and H_2O, and the gaseous or liquid wastes can be utilized to generate electricity by this catalytic engine.

Exemplary Embodiments Described

[0052] Using the teachings of the present invention, a number of different catalytic engine and system configurations are available to one skilled in the art.

[0053] For example, as shown in an exemplary embodiment in FIG. **1**, there is shown a reaction zone **1** in communication with a turbine **2**, which is in further communication with an electric generator **3**. Prior to feeding into reaction zone **1**, there is shown a water supply **4** from which water can be delivered by pump **5** to a purifier **6**. The purified water may be stored in purified water container **7**. The purified water is then mixed with a liquid fuel (such as ethanol, gasoline and surfactant mixture) from fuel supply **8** in mixer **9** to create a fuel mixture, and be fed into a heat exchanger **12** via pump **11** to preheat the hydrocarbon/alcohol mixture before feeding into the reaction zone **1**. Various control valves **10** are situated along the paths to control the % fuel, CO_2/C, H_2O/C and O_2/C ratios as needed. However, for some fuels, it is necessary to by-pass mixer **9**. They can be evaporated and heated separately, and be mixed with steam (water) after heat exchanger **12**. In the reactor zone **1**, the fuel mixture is reacted over the Pt group metal and/or commercial oxidation catalysts at a very high space velocity (residence time <300 milliseconds), and this high temperature and high pressure stream comprising steam and other gases is fed to the turbine **2** in communication with electrical generator **3**. Note that a back-pressure regulator **50** is used to control the pressure inside the reactor zone **1**. This regulator is used to regulate the reactor pressure and to control the gas speed to drive the downstream turbine. As known, the higher the reformer pressure, the larger the drop of pressure between the reaction zone and the turbine and, therefore, the faster the gas and the turbine speed.

[0054] Since excess oxygen is used in the feed mixture, complete oxidation reactions will occur over the Pt group metal and/or commercial oxidation catalysts in the reaction zone **1**, and will produce pollution free exhaust gas. The complete oxidation reactions will produce reaction heats to vaporize water and to generate a high-pressure steam. Since the oxidation reactions are very fast and complete, the reactor's outlet temperature is therefore closely related to the O_2/C of the feed mixture. Therefore, a thermocouple located at the outlet side of the reaction zone **1** can be used to adjust the O_2/C ratio of the gas mixture. In other words, this thermocouple is useful as a feedback controller for regulating the O_2/C ratio of the feed mixture.

[0055] After passing through the heat exchanger **12**, portion of this reformate stream can be recycled by pump **25** to provide steam and CO_2 to the engine's feed mixture, other portion of the exhaust gas can pass through a condenser **13** to recycled steam in tank **14** for future use, and the remaining gas can be vented into atmosphere.

[0056] In FIG. **2**, there is shown an alternative exemplary embodiment of the catalytic engine of the present invention. As shown in FIG. **2**, the water, air, fuel and the recycled reformate are fed separately into the reaction zone **19**. That is, air compressor **21** is used to pump air through its own heat exchanger **22**, and fuel pump **23** is used to pump fuel/water mixture through its own heat exchanger **22**A as well. If the fuel mixer is originally in a liquid state, then the heat exchanger **22**A is used to vaporize the fuel mixture to a gaseous state before injecting into the reaction zone **19**. The two components are fed separately into reaction zone **19** to produce a high-pressure stream comprising of steam. The reformate stream is then fed into a turbine **20** which is in communication with compressor **21**, pump **23** and an electrical generator **24**.

[0057] As shown in FIGS. **1** and **2**, the supplemental air and fuel lines can provide extra air and fuel (if necessary) to the reaction zones during the operation, especially at the start-up of this catalytic engine.

[0058] The catalytic engine can be connected to an adsorption/absorption tower **100** as shown in FIG. **3**. Here, the gaseous and/or liquid waste compounds, such as volatile organic compounds from a paint booth; industrial waste HC stream etc. can be concentrated inside this tower by using high surface area adsorbents or absorbents. Typical adsorbents/absorbents are activated carbons, aluminum oxide, silica oxide, zeolites etc. If these adsorbents/absorbents have reached their saturation capacity, the adsorbed/absorbed waste compounds inside the tower **100** can be purged out by the hot recycled exhaust gas by properly open/close valves **3** and **3**A, and the waste compounds can then be injected into the reactor zone **19** to be oxidized there.

[0059] The catalysts in the Oxidizer can be arranged as shown in FIG. **4**, where samples A, B, C and D are commercial oxidation catalysts or supported monolithic Pt group metal catalysts containing one or more metals, especially Pt, Pd, Rh, Co, Ni and Fe. The total individual or mixed metal loadings in each of the four samples can be the same, or they can gradually be increased in metal loading to form a gradient catalyst system as shown in U.S. Pat. No. 6,436,363. The diameter of these samples can be the same as shown in FIG. **4**. Also shown in FIG. **4**, there is a flame igniter or an electric ignition device E to initiate the catalytic oxidation reactions in the reaction zone. The ignition device E can be an electric hot wire, an electric glow plug, spark plug, plasma device or an electrically heated monolithic catalyst containing Pt group metals. However, the hot exhaust gas can sometimes initiate the CPO reactions without any external heat source, especially if the fuel or fuel mixture contains at least one low temperature light-off fuel.

EXAMPLES

[0060] The following examples are provided to merely illustrate the non-limiting scope of the present invention. One skilled in the art will readily understand that many additional variations and embodiments are encompassed by the present invention.

[0061] The following examples are based on thermodynamic calculations using the HSC Chemistry Version 4.1 software (Outokumpu Research Oy, Pori, Finland). For example, the equilibrium gas composition for a given fuel feed mixture is first calculated at temperatures between 100 and 2500° C. The calculated equilibrium composition at a given temperature is then used to calculate the adiabatic temperature raise from the initial gas temperature at 100° C. However, it is found that, over a certain temperature range, the equilibrium composition is a strong function of temperature, i.e. a small change in temperature will cause a large change in equilibrium composition and thus affect the calculated adiabatic temperature (Tad). Therefore, the equilibrium composition at a given temperature and the calculated adiabatic temperature (Tad) for this composition should be iterated continuously until these two temperatures are fmally

matched. However, to demonstrate the effects of H_2O/C and O_2/C ratios on the reactor's operating temperature, and the importance of controlling these two ratios, satisfactory conclusions can be reached by using the approximate calculated values (±100° C.) as shown in the following tables.

Example 1

[0062] 100 moles of various hydrocarbon mixtures comprising various amounts of methane and air are fed and reacted in the reaction zone. No water is used in this example. The calculated results from the HSC Chemistry Version 4.1 software are summarized in Table 1.

TABLE 1

Equilibrium Gas Composition and Adiabatic Temperatures (Tad, degree C.) for CH_4-Air Systems

				Equilibrium Gas Composition (moles)							
% CH4	H20/C	O2/C	Tad	N2	H2O	H2	CO	CO2	CH4	O2	C
4.76	0.00	4.20	1200.00	75.20	9.52	0.00	0.00	4.76	0.00	10.50	0.00
9.09	0.00	2.10	1980.00	71.80	17.90	0.25	0.64	8.45	0.00	1.35	0.00
16.67	0.00	1.05	1400.00	65.80	15.00	18.30	13.39	3.29	0.00	0.00	0.00
20.00	0.00	0.84	1110.00	63.20	10.60	29.40	17.00	2.96	0.00	0.00	0.00
28.57	0.00	0.53	690.00	56.40	4.96	47.20	18.60	3.23	2.51	0.02	4.25
33.30	0.00	0.42	657.00	52.70	7.14	50.80	13.50	3.67	4.34	0.01	11.80
41.18	0.00	0.30	605.00	46.50	10.80	52.80	6.84	3.54	9.39	0.00	21.40

This table lists the adiabatic temperature (Tad) as a function of % CH_4 (dry), and the product gas composition as a function of H_2O/C and O_2/C ratios. For O_2/C ratios of 4.20 and 2.10, complete combustion reactions can be expected thermodynamically since all CH_4 are converted to CO_2 (no H_2 and CO), and the adiabatic temperatures after combustion are 1200° and 1980° C. respectively. As the O_2/C ratios is shifted toward the lower values, more H_2 and CO and less amount of CO_2 are produced, indicating that the reaction mechanism is gradually shifting from the complete combustion reactions toward the partial oxidation reactions, and the calculated adiabatic temperatures are also gradually reduced to <1100° C.

[0063] As shown in Example 1, a sudden momentary increase in O_2/C ratio to a value over 1.05 can cause the catalyst's temperature over 1400° C., this will cause permanent damage and/or even melt the catalyst. Furthermore, low O_2/C ratios will produce coke (i.e. C). Thus, Example 1 confirms that U.S. Pat. No. 6,960,840 and other catalytic combustion technologies, which perform fuel combustion without water in the feed gas, are susceptible to thermal deactivation, coking and/or melting of its catalysts if the O_2/C ratio is not controlled properly.

Example 2

[0064] Example 1 is repeated, except 100 moles of water are added to the same 100 moles of CH_4 and air mixture. The calculated adiabatic temperature raise (Tad, degree C) and the gas composition are summarized in Table 2.

[0065] By comparing Tables 1 and 2, under the exact CH_4/air mixture, the addition of water will reduce the adiabatic temperature and avoid coke formation, as shown in Table 2.

TABLE 2

Equilibrium Gas Composition and Adiabatic Temperature (Tad, degree C.) for CH_4-Air-Water (100 Kmoles) systems

				Equilibrium Gas Composition (moles)							
% CH4	H20/C	O2/C	Tad	N2	H2O	H2	CO	CO2	CH4	O2	C
4.76	21.01	4.20	650.00	75.20	110.00	0.00	0.00	4.76	0.00	10.50	0.00
9.09	11.00	2.10	1080.00	71.80	118.00	0.00	0.00	9.09	0.00	0.91	0.00
16.67	6.00	1.05	820.00	65.80	105.00	28.10	3.54	13.10	0.00	0.00	0.00
20.00	5.00	0.84	700.00	63.20	97.90	42.10	4.28	15.71	0.01	0.00	0.00
28.57	3.50	0.53	520.00	56.40	87.40	58.20	3.04	19.80	5.76	0.00	0.00

The results in Table 2 indicate that the use of steam in the feed gas is a useful improvement over Example 1. It is believed that steam, which has a higher heat capacity compared to other gases, absorbs reaction heats more efficiently to keep all adiabatic temperature below 1200° C. Furthermore, the addition of water to the feed mixture will shift the equilibrium composition, avoid coke formation and will favor easier and more flexible reformer operations. Thus, the catalyst life can be extended with the use of steam in the feed.

[0066] As shown in this table, feed gas mixture containing 4.76% CH_4, H_2O/C=21.01 and O_2/C=4.20 will produce reformate at 650° C., and gas mixture containing 9.09% CH_4, H_2O/C=11.0 and O_2/C=2.10 will produce reformate at 1080° C. These two operating conditions can be used to generate

high temperature and high-pressure reformate to drive a turbine or a turbo charger. In other words, these two conditions can successfully be used in this invention.

Example 3

[0067] Example 1 is repeated except that 200 moles of water are added to the same 100 moles of CH_4 and air mixture. The calculated adiabatic temperature (Tad, degree C) and the gas composition are summarized in Table 3.

TABLE 3

Equilibrium Gas Composition and Adiabatic Temperature (Tad, degree C.) for CH_4-Air-Water (200 Kmols) Systems

				Equilibrium Gas Composition (moles)							
% CH4	H20/C	O2/C	Tad	N2	H2O	H2	CO	CO2	CH4	O2	C
4.76	42.02	4.20	470.00	75.20	210.00	0.00	0.00	4.76	0.00	10.50	0.00
9.09	22.00	2.10	770.00	71.80	218.00	0.00	0.00	9.09	0.00	0.91	0.00
16.67	12.00	1.05	600.00	65.80	203.00	30.80	0.92	15.80	0.03	0.00	0.00
20.00	10.00	0.84	525.00	63.20	195.00	44.70	1.03	18.80	0.16	0.00	0.00
28.57	7.00	0.53	440.00	56.40	190.00	50.90	0.65	19.70	8.18	0.00	0.00

Compared to Example 2, Table 3 shows that an additional 100 moles of water further reduces the adiabatic temperature in the reaction zone. Table 3 illustrates that in some cases (i.e. low O_2/C ratios), the reactor temperatures are too low, indicating that catalysts may lost their activities due to low operating temperatures and may have problems of producing high-pressure reformate. Thus, Table 3 confirms the importance of maintaining control and optimizing the % CH_4, O_2/C and H_2O/C ratios of the feed gas.

Example 4

[0068] Example 1 is repeated except that ethanol was used as the fuel source instead of methane. The results of these thermodynamic calculations are shown in Table 4.

[0069] As shown in Table 4, the adiabatic temperatures for the O_2/C ratios between 2.10 and 0.70 rose over 1400° C. and, thus, the catalysts will melt and/or become thermally deactivated. Even for the O_2/C ratio of 0.26, there is a risk of catalyst deactivation as a result of carbon formation, which will block the catalyst bed and cause flow disturbance. Therefore, like Example 1 with methane, Table 4 confirms that the use of ethanol and air without water in the feed mixture does not lead to a thermally efficient or successful operation of a catalytic reformer.

TABLE 4

Equilibrium Gas Composition and Adiabatic Temperature (Tad, degree C.) for Ethanol-Air Systems

			Tad	Equilibrium Gas Composition (moles)								
% C2H5OH	H2O/C	O2/C	(C.)	N2	H2O	H2	CO	CO2	CH4	O2	C2H5OH	C
2.44	0	4.2	985.9	77.1	7.32	0	0	4.88	0	13.2	0	0
4.76	0	2.1	1650	75.2	14.3	0	0.03	9.49	0	5.75	0	0
6.54	0	1.5	1760	73.8	16.9	0.038	0.121	11.2	0	2.79	0.901	0
9.09	0	1.05	1730	71.8	18.4	0.064	0.196	12.1	0	0.765	2.94	0
13.04	0	0.7	1460	68.7	18.8	1.01	2.14	11.1	0	0	6.43	0
16.67	0	0.52	880	65.8	11.7	38.3	26.7	6.66	0.06	0	0.06	0
20	0	0.42	685	63.2	7.71	47.9	29.7	8.09	2.19	0	0	0
28.5	0	0.26	630	56.4	15.6	57.7	19.5	11.7	6.22	0	0	19.7

Example 5

[0070] Example 4 is repeated, except 100 moles of water are added to 100 moles of ethanol and air mixture. The results of the thermodynamic calculations are shown in Table 5.

TABLE 5

Equilibrium Gas Composition and Adiabatic Temperature (Tad, degree C.) for Ethanol-Air-Water (100 Kmole) Systems

			Tad	Equilibrium Gas Composition (moles)								
% C2H5OH	H2O/C	O2/C	(C.)	N2	H2O	H2	CO	CO2	CH4	O2	C2H5OH	C
2.44	20.49	4.2	539.7	77.1	107	0	0	4.88	0	13.2	0	0
4.76	10.5	2.1	886.1	75.2	114	0	0	9.52	0	5.72	0	0
6.54	7.65	1.5	1140	73.8	120	0.008	0.002	13.1	0	0.012	0	0
9.09	5.5	1.05	1000	71.8	114	13.4	3	15.2	0	0	0	0
13.04	3.83	0.7	800	68.7	104	35.4	6.34	19.7	0	0	0	0
16.67	3	0.52	635	65.8	92.7	57.1	7.37	25.8	0.147	0	0	0
20	2.5	0.42	560	63.2	86.9	66.8	6.92	29.9	3.16	0	0	0
28.57	1.75	0.26	510	56.4	85.2	65.1	5.56	33.9	17.7	0	0	0

Table 5 shows that, with the addition of steam, complete combustion can be achieved under several O_2/C ratios and the adiabatic temperatures can still remain below 1140° C. without carbon formation. Therefore, these conditions can be chosen as the operating conditions for this catalytic engine. Furthermore, because of the difference in the latent heat, the results of Tables 2 and 5 indicate that the optima O_2/C ratio and the maximum % fuel to limit the reactor's temperature <1100° C. will depend on the fuels used.

Example 6

[0071] Example 4 is repeated, except 200 moles of water are added to 100 moles of ethanol and air mixture. The results of the thermodynamic calculations are shown in Table 6.

[0072] Like Example 3, Table 6 again confirns the reduction of operating temperatures and catalytic activities when excess H_2O is added. Again, the optima operating H_2O/C and O_2/C ratios to limit the reactor's temperature <1100° C. vary with the type of fuels used.

TABLE 6

Equilibrium Gas Composition and Adiabatic Temperature for Ethanol-Air-Water (200 Kmole) Systems

			Tad	Equilibrium Gas Composition (moles)								
% C2H5OH	H2O/C	O2/C	(C.)	N2	H2O	H2	CO	CO2	CH4	O2	C2H5OH	C
2.44	40.98	4.2	394.6	77.1	207.3	0	0	4.88	0	13.2	0	0
4.76	21.01	2.1	642.4	75.2	214.3	0	0	9.52	0	5.72	0	0
6.54	15.29	1.5	816.4	73.8	219.6	0	0	13.1	0	0.1	0	0
9.09	11	1.05	735	71.8	212	15.4	0.924	17.3	0	0	0	0
13.04	7.67	0.7	600	68.7	199	39.8	1.85	24.2	0.011	0	0	0
16.67	6	0.52	510	65.8	189	58.3	1.9	30.2	1.19	0	0	0
28.57	3.5	0.26	445	56.4	186	60.1	1.48	35.7	20	0	0	0

I claim:

1. A catalytic engine comprising the process steps of

a) Introducing a fuel mixture into a reaction zone of a fuel processor (reformer),

i). Said fuel mixture comprising of hydrocarbons (or bio-fuels), steam, recycled exhaust gas, and supplemental air, and said fuel mixture having a controlled amount of % fuel, H_2O/C ratio >1.0, O2/C ratio >1.0 and CO_2/C ratio up to 1.0,

ii) Said the reaction zone including one or more catalysts with each catalyst's compositions comprising one or more supported or unsupported metal and/or oxide oxidation catalysts,

b) Reacting said fuel mixture in said reaction zone of the fuel processor at a temperature between 150-1200° C. and a pressure between 1 to 100 atmosphere to produce a reformate stream comprising mainly of steam, CO_2, O_2 and N_2,

c) Using the high temperature and high pressure reformate stream to drive a steam turbine, turbo charger or any type of gas turbine.

2. The process of claim **1**, adjust individually or simultaneously the H_2O/C, CO_2/C and O_2/C ratios and the % fuel to obtain the optima operating condition for a given fuel mixture, and to control the maximum reactor temperature constantly below 1200° C. (preferably <1100° C.) and pressure between 1 to 100 atmosphere.

3. The process of claim **1**, wherein the residence time of the reactants inside the reaction zone of the fuel processor is <1 second, preferably <300 milliseconds (to reduce the reactor volume).

4. The process of claim **1**, wherein said the Pt group metal and other metal catalyst composition comprises one or more metals of platinum, palladium, rhodium, iridium, osmium, cobalt, nickel, iron, and ruthenium, and said the catalyst is

either unsupported as gauge, screen, wire mesh, foil or foam, or a total metal amount of >0001 wt % is supported on various ceramic or metallic substrates in the shape of monolith, pellet, bead, porous foam, plate, or static mixer.

5. The process of claim **1**, wherein said the oxide catalyst comprises one or more oxide of Al, Ca, Fe, Co, Mo, V, Ti, Cu, Ce, Zr, Zn, Re, Mg and Ni, and the oxide catalyst can contains other rare earth metal oxides and/or alkaline oxides as promoters or as thermal stabilizers, particularly oxides of lanthanum, praseodymium, yttrium, calcium, rhenium, barium, strontium, potassium, magnesium or the mixtures thereof.

6. The process of claim **1**, wherein said the Pt group metal and/or the commercial oxidation catalyst is supported on one or more mixture of washcoat materials, and the washcoat materials can consist of (1). One or more high surface area oxides of aluminum, copper, vanadium, cobalt, nickel, iron, cerium, zirconium, cerium-zirconium oxide, cerium-zirconium oxide composite, and (2). One or more washcoat thermal stabilizers such as rare earth metal oxides and/or alkaline oxides, particularly oxides of lanthanum, praseodymium, yttrium, calcium, rhenium, barium, strontium, Zinc, potassium and magnesium.

7. The process of claim **1** and claim **6**, wherein said the catalyzed washcoat containing of Pt group metal and/or commercial oxidation catalyst is further supported on various type of ceramic substrates selected from alumina, alumina-silica, alumina-silica-titania, mullite, cordierite, zirconia, zirconia-ceria, zirconia-spinel, zirconia-mullite or silicon carbide, and the substrate is in the shape of monolith, pellet, bead, porous foam, plate, or static mixer.

8. The process of claim **1** and claim **6**, wherein said the catalyzed washcoat containing Pt group metal and/or the commercial oxidation catalyst is supported on any metallic substrate which can sustain a temperature between 500 to 1100° C. and is in the shape of monolith, screen, mesh wire, foil, foam, static mixture, plate or heat exchanger.

9. The process of claim **1**, wherein said fuel consists of one or any combination of the fuels which theoretically can be vaporized and can be converted completely over a Pt group metal and/or a commercial oxidation catalyst to CO_2 and water, and the typical fuels are: C_1-C_{16} hydrocarbons (methane, LPG, gasoline, diesel, jet fuels etc), natural gas, sugar, glucose, animal fats, C_1-C_8 alcohols, vegetable oils, soybean oil, corn oil, olive oil, jatropha oil, bio-ethanol, bio-diesel, biobutanol, bio-methane, bio-fuels derived from biomass or from agriculture/industrial/animal wastes, or an industrial exhaust containing volatile organic compounds (VOC, mainly organic solvents).

10. The process of claim **1**, wherein said the inlet feed stream of the reformer (fuel processor) contains >20% water (steam), oxygen, fuels and other inert gases, and liquid water can optionally be injected into the reaction zone to absorb more reaction heat.

11. The process of claim **1**, wherein said the inlet fuel mixture of the reaction zone contains a re-circulated catalytic engine's exhaust gas, which contains steam and CO_2.

12. The process of claim **1**, wherein said any external heat source such as heat exchanger, hot wire, glow plug, spark plug or plasma device can be used to initiate the oxidation reactions during the start-up of the catalytic engine.

13. The process of claim **1**, wherein said the inlet fuel mixture of the reaction zone contains HC fuels, water and/or alcohols with optional amount of surfactants blended together to form a single phase aqueous mixture, and preferably the fuel mixture contains at least one chemical compound such as alcohol, unsaturated hydrocarbons, or other low boiling point starter fluid which can initiate the oxidation reactions in the reaction zone over the catalyst at a temperature <250° C.

14. The process of claim **1**, wherein thermocouples or temperature sensing elements are installed inside or outside of the reaction zone to function as feed back controllers for regulating the O_2/C ratio and for optimizing the performance of this engine.

15. The process of claim **1**, wherein a catalytic engine is used directly as a driving device for industrial, transportation, utility and household equipments such as lawn mower, chainsaw, weed eater, motorcycle, automobile, bus, truck, train, folk lift truck, weed eater or battery charger.

16. The process of claim **1**, wherein two or more fuel processors which are arranged in parallel to each other can simultaneously provide each reformate gas to drive a single steam turbine/turbo charger/gas turbine.

17. The process of claim **1**, wherein a single fuel processor can provide the reformate gas to drive simultaneously several steam turbines/turbo chargers/gas turbines which are arranged in parallel to each other.

18. The process of claim **1**, wherein the recycled exhaust gas line of the catalytic engine is connected to a waste fuel concentrator to form an integrated pollution removal system.

19. The process of claim **1** and claim **18**, wherein a fixed or fluidized bed concentrator can use various high surface area adsorbents and/or absorbents such as aluminum oxide, silica oxide, zeolite, activated carbon and/or other oxides to collect and to remove any combustible volatile organic pollutants or waste fuels from a contaminated gas or liquid stream.

20. The process of claim **1** and claim **18**, wherein the adsorbed/absorbed waste fuels in the pollutant concentrator can be purged out of the system and the adsorbents/absorbents can be regenerated in situ by passing a hot recycled exhaust gas through the concentrator and then by injecting the gas stream into the catalytic engine's reaction zone to produce heat as well as to remove the pollutants.

21. The process of claim **1**, wherein the catalytic engine is connected to an electrical generator and a battery bank to form an integrated system as a stand alone stationary or mobile power station.

22. The process of claim **1** and claim **21**, wherein the integrated system can provide electricity to power the electrical devices/equipments used in industrial, transportation, utility and household applications, such as battery charger, electric car, truck, bus, motorcycle, lawn mower, folk lift truck, weed eater or train.

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